research review

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Magnetic Wind-Tunnel-Model Suspension & Balance Systems

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When an aerodynamic model is tested in a wind tunnel, it is normally attached to one or more support struts or wires which hold the model in the air stream. Regardless of how small the support mechanisms are made, the air flow around the test model is influenced to some extent by the presence of the support. Therefore, any test data obtained are subject to adverse support-interference effects.

For years the wind-tunnel aerodynamist has dreamed of the ideal system where the model is floated in the test section with no visible or mechanical means of support. This fantasy has now become a reality, through new and novel applications of magnetics. For instance, it is now possible to suspend the aerodynamic test body in a system of electromagnetic fields with no support gadgetry to interfere with the flow (Fig. 1). The aerodynamic forces and moments acting on the body can be determined from the restraining magnetomotive forces required to hold the model in a desired attitude and position.

The feasibility of the magnetic wind-tunnel-model suspension system was first demonstrated by the French organization ONERA (National Office of Aerospace Research) circa 1957. Subsequently, studies of the system were begun in the United States. The two U.S. leaders in this work area are the Massachusetts Institute of Technology, whose effort has been sponsored by ARL since 1960, and the University of Virginia. Since the success of the early ONERA balance, which had the capability of measuring small lift-and-drag forces under steady-state conditions, great advances have been made. For example, MIT has just completed the design of a 6-component magnetic suspension and balance system for ARL which, through bench tests of various components, has been shown to have over-all measurement accuracies greater than the typical strain-gage balance. Further, this balance will have a dynamic testing capability such that the model can be oscillated in pitching or plunging motions in the range of reduced frequencies which are of interest in full-scale atmospheric re-entry flights. This balance will accommodate dynamic pressure loads up to 4.0 psi at Mach 10. The system is sized to operate in conjunction with a wind-tunnel nozzle having a 12-inch-diameter exit, and with provision for the adaptation of a 10-inch schlieren optical system.

An outstanding feature of this new balance system is the advanced model position-

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measuring method which has been developed by MIT; this technique employs an electromagnetic sensing system which is independent of the direct-current suspension magnetics and which operates with a high-frequency alternating field which minimizes mutual interference. Extreme accuracies have been achieved in tests of this scheme, which makes the former optical position-measuring method obsolete.

Large electric powers are required for these magnetic support systems; the present new system designed for ARL will require a maximum of about 4.5 megawatts. All magnetic coils in the system will be internally cooled with forced water flow. Future development effort will likely cover the possible application of superconductors which conceivably could greatly reduce the power required and the size of the magnetic coils. (The present complete system will weigh an estimated 13 tons.)

In the interest of assessing the pertinent state-of-the-art, an international symposium on this subject was sponsored by ARL. The meeting was held at Wright-Patterson AFB on 13 and 14 April 1966, and is summarized in Ref. (1). Papers describing their accomplishments were presented by all those organizations which have been actively engaged in the investigation of the problems of the magnetic balance system. Also, most of those organizations in the USA which were known to be potential users of the system

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JACOB SEIDEN
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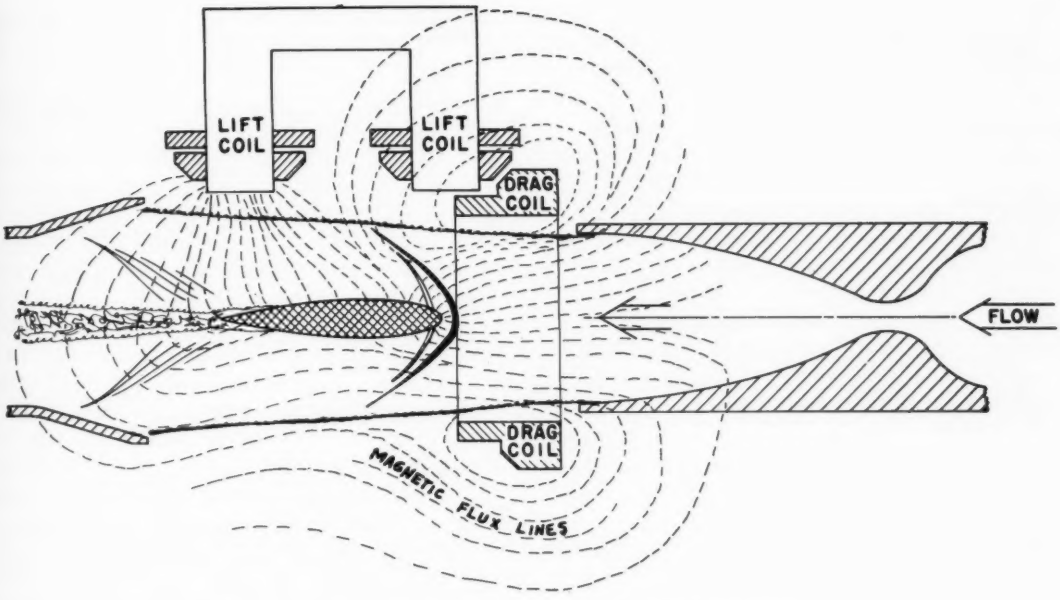

Figure 1. Magnetic wind-tunnel-model suspension system.

were represented at the symposium. Based on the results of the meeting, it appears that the magnetic suspension and balance system will find an important application in the field of dynamic stability. At the present time, planar coupled oscillatory motions, such as pitch-yaw, could likely be handled, but further development is required before more complex modes become manageable.

Wind-tunnel studies involving rolling motions where the instantaneous roll position must be known at all times still pose a problem, since the new magnetic model position-measuring method is not adaptable to the roll degree of freedom; the optical device is still used here. However, in the study of magnus forces related to spinning bodies, the immediate magnetic balance application looks very promising. Measurement of temperature and pressure distribution over the test model also can be made using telemetering equipment located in the model. Further effort is required toward miniaturization of the telemetry instrumentation in order to get more than 4 channels in a model, which is about the present limit. Free-flying tele-controlled test models for aircraft-configuration evaluation, and investigation of rocket interstaging problems are also some of the more interesting possible applications discussed at the symposium.

It should be noted that, although it may sound as though most of the problems have been solved, the magnetic suspension system is quite new and essentially still untried. So far, there is only speculation as to the complete usefulness of the sophisticated 6-component systems. Consider, for example, that MIT has the only operable 6-component system in this country; and it is small, operating with a 4" x 4", Mach-4.8 nozzle. The capabilities of this system are far below those of the new MIT design described earlier. Further, the University of Virginia group works with only the 3 force components (no moments). Princeton University so far has worked essentially only with drag. AEDC has designed and built a prototype 5-component system which has not yet been tried in conjunction with a wind tunnel. Probably the most advanced system in Europe is in operation at the University of Southampton. This is a 6-component system, employing all solid-state electronics; but so far, it has had limited use at only low subsonic speeds. A 5-degree-of-freedom system is in operation

at the Royal Aircraft Establishment at Farnborough, England, on a 7-inch, Mach-8.0 tunnel. Here, the only reported results to date cover some cone-shaped model drag measurements.

Obviously, the magnetic suspension and balance system is still in its infancy. However, the total development effort and the rate of progress are steadily increasing and have reached the point where it now appears that this device is no longer merely a laboratory curiosity, but is rather fast becoming an accepted and useful aerodynamic testing tool.

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Mr. Fred L. Daum, an aerospace research engineer with the Research Branch, Fluid Dynamics Facilities Research Laboratory, ARL, has been engaged in the study and development of magnetic wind-tunnel-model suspension and balance systems. He is also extending his previous studies of air condensation to further explain the physical mechanisms involved in testing in supersaturated air flow, and to establish what limitations, if any, apply to such testing. Mr. Daum received his B.S. in Aeronautical Engineering from the University of Cincinnati in 1941, and has done graduate work at the Ohio State University Graduate Extension School. He spent several years with NACA at Langley Field, Va., and with AMC at Wright Field before joining ARL in 1950. He is a member of the American Institute of Aeronautics and Astronautics, and has a number of publications to his credit.

Automata Theory

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The development of the digital computer heralded a new era in science and technology; in fact, it has had an impact on all phases of modern existence. It is used as a tool for computation and as an integral part of systems development ranging from automobile production to guidance of sophisticated space vehicles. Yet, there are severe limitations on a computer's capabilities. Although there have been many technological advances, such as the design of smaller components and better memory techniques, the fundamentals have not changed in the past 25 years, due to a lack of the related mathematical formalism we call "automata theory." However, results of the AFOSR-supported program in automata theory promise to lead to a wide range of new theoretical advances in computer technology.

Automata theory began in 1939 with the classical work of Shannon on switching circuits. The theory of sequential machines, where time plays an essential role, was established in the McCulloch and Pitts paper of 1943. Thereafter, the theory developed slowly because no mathematical formalism was available.

Almost concurrently with the theory, digital computers were developed. These are finite-state sequential machines. The approach to the construction of computer hardware was the intuitive one. The engineer, confronted with the problem of realization of any particular sequential circuitry, and knowing how many registers, words of memory, and so forth, were required in the past to construct similar devices, used his experience and ingenuity to connect the chosen components in the most advantageous manner. Frequently, after the machine was in operation, a considerable redundancy was discovered. Whole blocks of components could be eliminated without in any way impairing the desired operation. Even though there were a number of techniques for dealing with nonsequential circuit design, it was an art to which long experience in practical problems was the sole

initiation. The situation was similar to that existing in classical mechanics before the introduction of the Hamilton-Lagrange methods. Obviously, what was required in sequential machine design was a canonical representation furnishing a technique by which a complete set of irredundant equations, characterizing the desired system, could be obtained almost mechanically. In addition to the immediate design application, such schemes could constitute a general structure theory of sequential machines, leading to a really profound understanding of finite-state sequential systems in general.

In 1962, the first basis of an algebraic theory of finite-state sequential machines appeared. It established that the needed mathematics was the theory of finite semigroups, and introduced the one new idea: that of a relative measure of the computing power of finite machines. This was a key to the decomposition of finite machines into a natural set of irreducible component machines.

With the establishment of a sound mathematical basis for the theory, and its potential to develop the needed mathematical formalism, the Applied Mathematics Division of AFOSR (OAR) initiated a support program in automata theory. Two goals were envisioned: first, to furnish an automatic, programmable technique for minimal physical realization of finite-state machines; and second, to provide fundamental understanding of the essential notion of finite-state systems in general. A wide range of applications was anticipated. Machines could be designed automatically by computers without human intervention. Special-purpose computers, such as those required for onboard space-vehicle systems, could be realized with minimum weight and cost. Many systems with finite-state representations, e.g., long-chain molecules and biological systems, could be studied carefully. At the very least, the research would yield more efficient programming methods which should save more than the cost of the investigation.

The algebraic theory of machines is a complete structural study using algebraic methods, particularly those of the theory of groups. This allows, for the first time, the application of the enormous fund of sophisticated results of classical and modern algebraists to computer engineering. The most elementary use of the theory is to construct, given the input-output relation desired, the minimal finite-state machine realizing this relation.

To understand the ideas, we need a few definitions. Machine A is said to divide machine B if and only if any calculation A can do can be done by B, possibly aided by memoryless input-output codes. A semigroup is a set of elements closed under an associative operation. Semigroup A divides semigroup B if and only if A is a homomorphic subimage of B, i.e., intuitively, if and only if A is algebraicly simpler than B.

The initial observation is that machine A divides machine B if and only if A's semigroup divides B's semigroup. Here we have an engineering property which is difficult to establish equivalent to an easily verified algebraic property.

A machine is called prime if, whenever it divides a series-parallel (loop-free) network of other machines, it divides one of them. That is, a machine is prime if it can never profitably be loop-free constructed out of weaker ones. In view of the stringency of the definition, it is not clear that any prime machines exist. A very long algebraic construction and proof shows that there is, in fact, an infinite number of them and gives a complete characterization of the primes. It is well known that any integer can be represented as a product of the primes that divide it. For example, the number 200 is divisible by only two primes, 2 and 5, and can be expressed as 2^3 and 5^2. It is amazing that a corresponding fact is true for the much more complicated set of computing machines. This construction immediately allows solution of the state assignment problem for a wide category of cases.

Suppose an engineer wishes to realize in hardware a given N state sequential machine M (i.e., the abstract logical formulation of the circuit). Assume that flip-flops, cores, or any other binary elements are the basic memory objects.

In the literature, this is the sole case treated. It should be noted here that the

approach via the algebraic theory of machines leads to a method equally applicable to n-ary elements for any n greater than 1.

The engineer proceeds to select an integer k such that 2^k is equal to or greater than N. He then assigns to each state of the machine M a configuration (k-tuple) of elements such that two different configurations correspond to two different states. Once this assignment is made, the diode logic of the hardware is uniquely determined by the sequential machine M. In general, the next state of each binary element is dependent upon both the present input and the last state of all the binary elements. In this arbitrarily bad state, we may measure the complexity of the diode logic by saying that there are k^2 dependencies. In general, dependencies of the order of $\frac{4k^2}{5}$ are considered excellent, using the forgoing techniques.

However, using the algebraic theory of machines, M is decomposed into a series-parallel network of prime machines, where the product of the number of states of the component machines is equal to the number of states of the original machine M. States are assigned to the component machines arbitrarily. This operation, through the connecting codes of the decomposition, automatically induces a state assignment for M. Now, it is clear that we can number the component machines 1 to q so that in all, between the i^{th} machine and the input to the network, there are no more than i-1 intermediate machines. The logic of the 1st machine will depend only on the binary elements which realize this machine, and the logic of the i^{th} machine will depend only on its binary elements and the i-1 machines which precede it. Consequently, the number of dependencies is of the order of $1 + 2 + \cdots + k = \frac{k^2}{2}$ (approximately).

Thus, in this application, the complexity of the machine M is reduced in the ratio 8:5.

In general, the theory of machines can be regarded as a theory of optimum coordination of phase spaces, where phase space is the set of states of machines whose outputs are the same as the current state. In fact, the precise notion of what is meant by the term "physical theory" is just a transparent co-ordination of the phase space over which the theory operates. Problems in mechanics, for example, lead directly to the correct choice of generalized coordinates, and the seven integrals of motion are seen to correspond to the first machine and the machine decomposition of phase space. It is in the case of discrete phase space where the techniques of differential equations are not applicable that important breakthroughs are anticipated using this algebraic theory.

A new method for generating Boolean functions has been developed. A fixed simple Abelian-group machine M is used, and any Boolean function B can be realized by M with the aid of a storage sequence depending on M and B. This means that one finite-state machine can be used to realize all Boolean functions involved in a given operation with only a storage unit required for each Boolean function. This could lead to significant new techniques in the optimization of design of computer components.

A system for determining semigroup isomorphisms (equivalences) has been programmed to Project MAC. The program required 20 seconds to find an isomorphism of the cyclic group of order 12 with the direct product of the cyclic groups of orders 3 and 4. Decomposition of semigroup of order 64 factorial has been achieved.

A study of the application of the theory to biology has been initiated. A state input model for metabolic processes has been developed whereby a semigroup can be found underlying a given multienzyme system. The theory proves that the semigroup of any enzyme system can be represented by a system of simpler components. Information theory indicates that the components which are biologically significant are those known as simple non-Abelian groups (SNAG's), all others being insufficiently adaptive to maintain vital functions in the fluctuations of environment to which living organisms are subject.

This program represents the first application of nonlinear mathematical modes to biology. There are considerable implications

for medical research inherent in the theory, in that it provides insight into pathological processes.

Work has been started, using the techniques of the theory of machines, to attempt to clarify the theory of elementary particles.

The pioneering aspect of the algebraic theory of machines, which to a large extent was sponsored by AFOSR, will be concluded by bringing together a number of investigators, whose results in various aspects of automata theory and applications will be discussed. The proceedings of this conference will be published and form a cohesive reference for future research.

There are three major aspects for the continuing research:

(1) Pure research to develop a complete structure in the theory itself.

(2) Immediate applications to computer sciences, languages, and related fields.

(3) Use of the theory as a tool for better understanding of biological and physical systems.

Concurrent with its support of the algebraic (structure) theory of machines research, the Applied Mathematics Division of AFOSR has funded other approaches to automata theory. These include the reliability of sequential machines, the synthesis of time-varying sequential circuits, linear sequential circuits, error-correcting codes and nonbinary switching and logic.

There are two approaches to the effects of errors in sequential machines. One is to assume that the machine has somehow arrived at the wrong internal state and then consider the effects of these errors. The second is to consider the effects of errors on the inputs. In this model, one specifies input words which may be in error by giving an error relation on the class of input words. In the investigation, both internal errors (incorrect state transitions) and external errors (inputs which are not received properly) were considered. One result was obtained by the study of the class of automata which correct a prescribed set of input errors. It was found that there is an exchange between the error-correcting capabilities of a machine and the time necessary for correction.

Another part of the program is to develop a general theory through which any linear sequential circuit can be analyzed and synthesized. In particular, the investigation is concerned with the characterization and design of stable circuits, where any error input vanishes in a finite time, and quasistable circuits, where input error produces a perpetual but constant response. These circuits, which are singular, have been largely ignored in the past, but can be used to advantage in error-correcting and detecting systems. Techniques for constructing minimal forms of linear modular sequential circuits and for singular circuits have been developed very recently.

An examination of the problem of minimization of Boolean functions through graph theoretical methods is being pursued. It may be that this approach to minimal synthesis is preferable to existing algorithms.

In most automata, the logic is two-valued, based on binary switching theory. There appears to be considerable potential in multivalued logic for automata, so the development of nonbinary switching theory is another area into which the program in automata theory reaches. Ternary algebras have been developed and synthesis techniques for minimum-cost ternary switching circuits were derived in the context of available technology. Efforts are now under way to establish design techniques for nonbinary cellular arrays as well as for nonbinary, nonlinear sequential circuits.

The Applied Mathematics Division of AFOSR has thus developed a broad-based program on research in automata theory which encompasses both the structural and the programming approaches. There are, necessarily, overlaps and interchanges between these approaches and between automata theory and other areas such as information theory and biology. These interchanges are encouraged with the objective of advancing the frontiers of all the sciences involved and their eventual applications.

Psychophysical Relations In Adaptation Processes

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Professor Gosta Ekman, of the Perception and Psychophysics Unit, Psychological Laboratories, University of Stockholm, Sweden, has been conducting research on the psychophysical processes of human perceptual adaptation to continuing stimulation of the various sensors. This research is being supported by AFOSR.

In contrast to most other work in this field, Ekman and his co-workers use the methods of psychological scaling for direct measurement of perceptual intensities. Adaptive processes at the supraliminal levels are measured with perceived intensity as a function of time and with stimulus conditions as independent variables. The relation between adaptability and form of the psychophysical function, as well as the relation between perceived range and discriminative capacity, are developed. The research is intermodal, with the focus on general adaptation and such related processes as temporal integration of sensation before adaptation takes place, and recovery of sensitivity after adaptation has occurred.

DARK-ADAPTATION

Results of the research on dark-adaptation (1) are: 1) The growth of sensitivity is composed of two functions, intersecting at about 8 minutes. These functions are less curved than the corresponding threshold functions previously reported by other investigators. 2) There is a relatively sudden retardation of growth in sensitivity at about 18 minutes. 3) The data can be represented by a mathematical function defined as the sum of 2 logarithmic time functions.

Data obtained in this type of experiment, involving measurements of actually perceived brightness, are radically different from data based on experiments using detection thresholds or equal-brightness matching. The growth of brightness with time of dark-adaptation has never before been directly investigated.

The function which accounts for the sensitivity growth during the first 8 minutes, and which may be characterized as a retinal cone function, represents a process that continues during the whole adaptive period, whereas the second function, a retinal rod function in a restricted sense, appears to represent a rapid process limited to the 8 to 18 minutes after onset of dark-adaptation. The experimentally observed sudden retardation of growth of sensitivity at about 18 minutes is explained in these terms.

OLFACTORY ADAPTATION

Perceived olfactory intensity was studied as a function of time of constant olfactory exposure to hydrogen sulfide. The perceived odor intensity decreases regularly, at a decelerating rate, with time of exposure to the constant stimulation, and reaches an asymptotic level within the experimental period. The time at which this level is reached appears to vary regularly with level of stimulation. The trend of the experimental data is well approximated by simple exponential functions.

The report of this work is being prepared for publication.

UNPLEASANTNESS

The unpleasantness and subjective duration of a 50-cycle alternating electric current applied to two fingers were scaled by human subjects (2). Stimulation was varied in magnitude and duration. It was found that 1) unpleasantness increased logarithmically with stimulus duration; 2) unpleasantness was a power function of intensity, and subjective duration was linearly related to stimulus duration; and 3) subjective duration increased logarithmically with intensity.

BRIGHTNESS

The logarithmic function was verified for brightness, loudness, and vibratory intensity.

SUMMARY

This research may be summarized as follows: 1) The logarithmic function describing the process of temporal integration is now a fairly well-established principle. 2) Adaptation is an exponential function of time in olfaction. 3) Recovery of sensitivity upon termination of continuous stimulation to which adaptation has occurred is a composite logarithmic function in vision, loudness, and vibratory intensity.

EKMAN'S LAW

The noted psychophysicist, Professor S. S. Stevens of Harvard University, regards Ekman's work as so important that he proposes to summarize the results as "Ekman's Law." He writes: "Since it seems more important to have established the empirical generality of a principle than merely to have conjectured it...., it would appear that the principle of the linear growth of subjective variability deserves to be called Ekman's law, the subjective counterpart of Weber's law." And again: "The principle states that variability measured in psychological units is linearly related to psychological magnitude measured in the same units." (3)

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Basic Research in Approximation Theory

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Modern science and technology deal with information to be gained from data which may have as their sources observations of a physical, social, economic, or scientific event. Given large amounts of such data, the questions of their analysis and the validity of the conclusions to be drawn from such analysis are vital ones. Frequently, too many or too few observations of given events tend to obscure the real nature of the phenomena being studied. Thus, starting with a given set of data, one attempts to describe it by means of a curve or a graph or a function. The first such curve one might attempt to use to describe a given set of data is a polynomial, $p(x) = a_0 + a_1 x + \ldots + a_n x^n$, of degree n with real coefficients defined on a closed interval of real numbers [a,b].

Modern high-speed computers allow one to process large quantities of data very rapidly; hence, a basic knowledge of the process of approximating a given function or of finding a given function which adequately represents the data of some sequence of events is extremely important.

The classical Weierstrass approximation theorem states that any continuous real-valued function defined on the closed interval of real numbers [a,b] is the limit of some uniformly convergent sequence of polynomials. This is clearly equivalent to the statement that such a function can be uniformly approximated by polynomials to within any degree of accuracy.

In an attempt to explore the general area of approximation theory, with the support of AFOSR, Professor E. W. Cheney (1) of the University of Texas, gave a simplified proof that every continuous function on the closed interval [a,b] possesses a unique best approximation-in-the-mean by polynomials of degree equal to or less than n. Results concerning algorithms for the rational approximation of functions have been obtained by E. W. Cheney and H. L. Loeb (2).

In most cases the determination of a best approximation is a complicated numerical process which involves the solution of systems of nonlinear equations. Due to this difficulty, various approximate methods are often substituted. Results in this area have been obtained by T. J. Rivlin and E. W. Cheney (3).

Work has also been carried out by E. W.

Cheney and H. L. Loeb (4) on the continuity of rational approximation of operators, the mean-square approximation by generalized rational functions by E. W. Cheney and A. A. Goldstein (5, 6) of the University of Washington, and Tchebycheff approximation and related extremal problems.

Further work is being carried out in the areas of Tchebycheff approximation and nonlinear operators. Other AFOSR-sponsored efforts in this area are being carried out by Professor Porcelli of Louisiana State University, Professor Lorentz of Syracuse University, Professor Curtis of the University of Miami, Florida, and others.

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a brief look at thermoelectricity

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The study of thermoelectric effects in materials is interesting to both the engineer and the scientist. The engineer may be seeking the right choice of materials to construct a thermocouple for temperature measurements in an unusual or extreme environment, or to develop a solid-state refrigerator, or perhaps a source of electric power directly from heat. The scientist, on the other hand, may be trying to understand how energy and matter propagate in a material medium.

Three thermoelectric effects are known:

1. The Seebeck Effect. Seebeck reported in 1821 to the Prussian Academy of Sciences that he had observed an emf in the circuit of two different materials when their junctions were at different temperatures. The Seebeck coefficient, Q (to be defined below), is a measure of the magnitude of the effect for a given material.
2. The Peltier Effect. In 1834, Peltier reported a temperature difference between the junctions of two different materials when an electric current was passed around the circuit. The temperature difference could be made to reverse when the direction of the current was reversed. The Peltier coefficient, π (to be defined below), is a measure of the magnitude of the effect for a given material.
3. The Thomson Effect. Thomson (Lord Kelvin), in 1854, found that there was heating due to the passage of electric current through a material subject to a temperature gradient in addition to the irreversible Joule heating. This "Thomson heat" is proportional to the electric-current density and the temperature gradient. He also demonstrated the existence of the following relationship between the Seebeck and Peltier coefficients:

$$\pi = QT,$$

where T is the absolute temperature. He based his arguments on thermodynamics and some additional assumptions not covered by the first and second laws of thermodynamics*.

There may be a fourth thermoelectric effect, the so-called Benedicks Effect, but its existence is not well established.

**Since thermodynamics is a science restricted to the description of equilibrium states of systems and not to the description of the processes by which systems go from one state to the next, it is not surprising that Kelvin had to invoke additional assumptions. Later these assumptions were put on a firmer basis with the development of irreversible thermodynamics.*

The transport equations for heat and electric-current density can be derived by the method of Boltzmann or by the techniques of irreversible thermodynamics. In either case, the linear transport equations are (for single current carrier):

$$\vec{U} = K_{11} \vec{E} + K_{12} \vec{\nabla} T, \text{ and} \qquad (2)$$

$$\vec{J} = K_{21} \vec{E} + K_{22} \vec{\nabla} T, \qquad (3)$$

where the transport of matter has been neglected. In the above equations, $\vec{U}$, $\vec{J}$, $\vec{E}$, $\vec{\nabla} T$ are respectively the heat current density, the electric-current density, the electric field, and the temperature gradient. The K_{ij} are the transport coefficients. Inspection of Eq. 3 reveals that K_{21} is the electrical conductivity σ.

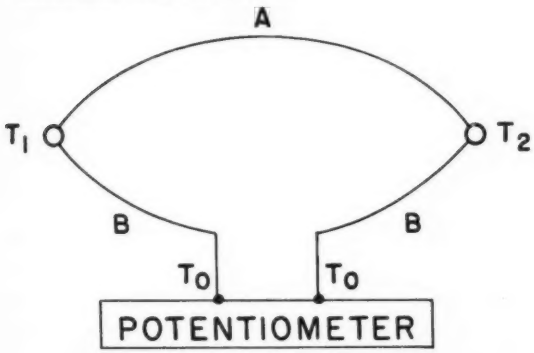

Figure 1. Thermoelectric circuit.

Consider the circuit shown in Figure 1 consisting of the two different materials A and B, their junctions at the temperatures T_1 and T_2, and a potentiometer for emf measurement. The potentiometer is connected into the circuit at an intermediate temperature T_o. The following discussion will be limited to the first two thermoelectric effects mentioned above.

If the current in the circuit is zero, and a temperature gradient exists, i.e., $T_1 \neq T_2$, then from Eq. 3 an electric field must exist:

$$\vec{E} = -\frac{K_{22}}{K_{21}} \vec{\nabla} T = Q \vec{\nabla} T. \qquad (4)$$

Eq. 4 defines the Seebeck coefficient Q. The emf, Φ, measured by the potentiometer can be obtained by integration of the electric field around the circuit:

$$\Phi = -\oint \vec{E} \cdot d\vec{r} = -\oint Q \vec{\nabla} T \cdot d\vec{r}$$

$$= \int_{T_1}^{T_2} (Q_A - Q_B)\, dT \approx (Q_A - Q_B)\Delta T, \qquad (5)$$

where Q_A and Q_B are the Seebeck coefficients for materials A and B. The last result follows if $\Delta T = T_2 - T_1$ is small enough such that the difference $(Q_A - Q_B)$ is essentially constant over the temperature interval. From Eq. 5 it should be noted that only differences in Seebeck coefficients can be measured and that the thermocouple emf has its source in the body of the materials not at the junctions. If the temperature gradient is zero and an electric current is maintained in the circuit, i.e., if the potentiometer is replaced with a battery then, upon solving Eqs. 2 and 3, the heat current density is

$$\vec{U} = \frac{K_{11}}{K_{21}} \vec{J} = \pi \vec{J}. \qquad (6)$$

That is to say, an isothermal flow of heat from one junction to the other can be maintained by the electric current. Eq. 6 is of fundamental importance in the design of Peltier refrigerators.

Consideration of the various microscopic properties of materials, i.e., the type of charge carriers, their effective mass, the types of scattering they undergo, and so on, enables the theoretician to calculate the transport coefficients. The experimenter measures the various coefficients--σ, π, Q, and so forth--and from these efforts obtains a better understanding of the transport properties of materials.

Since the oxidation of a metal is a process involving the transport of matter and electric charge through the oxide layer, knowledge of the transport properties of oxides could lead to the development of materials with greater oxidation resistance than are known at present. The use of such information is of obvious value to anyone designing a space vehicle for re-entry into the atmosphere or any other device subject to an oxidizing environment.

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Optimal Control and Nonlinear Programming

CAPTAIN ALLEN D. DAYTON, Directorate of Mathematical Sciences, AFOSR

In the last few years much research has gone into the optimal control problem. This problem has important applications in such areas as aerospace vehicle engineering, physiology, and economic theory. For instance--How is a spacecraft guided from planet to planet to minimize the amount of fuel needed? How does insulin secreted by the pancreas control the metabolism of carbohydrates in the human body? What is the best method to control inflation in the economy and at the same time hold unemployment to a minimum? These are all examples of problems that can be formulated as optimal control problems. The basic idea is that there exists some criterion function that one wants to either maximize or minimize subject to differential-equation constraints describing the mathematical model of the system.

Also, in the past few years, the nonlinear programming problem has evolved separately. This problem has applications in such areas as applied mechanics, diet selection, electrical networks, and management. For instance--What is the best design of a pin-jointed truss? What is the most economical way to feed a group of people so that certain nutrient requirements are met?

Recently, Dr. Lucien Neustadt of the University of Southern California, whose research is supported by AFOSR, formulated an abstract variational theory which subsumes both of the above problems as well as others. Dr. Neustadt formulates a very general variational problem, and derives the necessary conditions which solutions of this problem must satisfy.

The variational problem is formulated in the setting of a locally convex linear topological space. The basic concepts in this formulation are those of an internal cone, a first-order convex approximation and a particular type of differential. This threesome, roughly speaking, represents a "linearization" of the constraints imposed by the problem. Of the three, the most unorthodox is the first-order, convex approximation, which turns out to be a quite natural extension of the cone of attainability introduced by Pontryagin, Boltyanskiy, and Gamkrelidze, and of the convex set of linear variations introduced by Gamkrelidze in his work on quasiconvexity. Dr. Neustadt infers the first-order, convex approximation is the most suitable device for handling variational problems which include constraints in the form of ordinary differential equations. The necessary conditions satisfied by solutions of the general variational problem are in the form of a separation theorem for two convex sets, one of which is the set described above, and the second of which is related to the other two "linearizations" of the constraints. This canonical optimization problem includes, as special cases, virtually all the optimal control problems based on ordinary differential equations or difference equations, including the conventional optimal control problem (both with and without bounded-state variable constraints and with fixed or variable endpoints and initial and terminal times), discrete optimal control problems, and minimax control problems.

The necessary conditions for this problem include as a special case all the first-order necessary conditions in the classical calculus of variations, as well as the Pontryagin maximum principle and its various extensions and generalization. In addition, it is now possible to obtain necessary conditions for problems which heretofore have been outside the realm of applicability of any existing variational theory. Dr. Neustadt also indicates how a particular case of the canonical optimization problem can be looked upon as a mathematical programming problem in a locally convex linear topological space. He obtains necessary conditions which are generalizations of the well-known Kuhn-Tucker conditions.

Rapid Unmasking Of Disease Agents On the Horizon

MAJOR CHARLES E. FULLER
Directorate of Life Sciences, AFOSR

A most interesting research program, with a broad spectrum of possible future application, is that of General Electric chemical engineer John Gould and Cornell University microbiologist Martin Alexander. This AFOSR-sponsored program seeks to eliminate the time-consuming, laborious, and often inconclusive traditional laboratory procedures whereby various media and biochemicals are used to identify disease organisms.

Medical and clinical diagnosis have often been withheld in the past pending receipt of laboratory results, with medication for the patient being prescribed on an empirical or a clinical syndrome basis. Disease resolution, or demise of the patient suffering from an acute condition, could result prior to the receipt of pathogen identity, and selection of the most optimal antibiotic or chemotherapeutic agent.

Opportunities may exist in the future for public-health epidemiologists to ascertain quickly the bacterial villain when confronted with diseases of epidemic proportions. The advantage of quickly unmasking a pathogen exotic to this country, and introduced from elsewhere in the world, is obvious. As in other forms of combat, medical combat of a disease-causing organism is dependent on the identification of that organism. This cloak of anonymity may be lost forever, since research has indicated that different bacterial genera, species, and strains each excrete metabolic wastes that are chemically distinct. These wastes are subjected to chromatography, with the separate chemical compounds passing through the chromatograph column with distinct but separate speeds. These results are then graphed out as chromatograms, thus producing a unique signature, or fingerprint, of the 'unknown organism subjected to scrutiny. When these chromatograms are compared with those of known bacteria, their exact identity can be ascertained.

This brief procedure is prefaced by the transfer of an unknown inoculum into a chromatographically clean medium which will continue to support the transferred culture inoculum in a growth fashion. The medium selected that conformed to the needs of this procedure best is a modified Proom-Knight medium. This supportive substrate is composed of inorganic salts, amino acids, and vitamins combined with glucose solution and a miniscule amount of peptone. Tubes containing 5 ml of this modified Proom-Knight medium receive 0.1 ml of the unknown inoculum and are then allowed to incubate at 35° C for 40 hours. During this period the bacteria in question exercise their metabolic right to excrete unneeded wastes and metabolic byproducts into the modified Proom-Knight medium. These excretory products are separated from the bacterial cells which were their source by acidification and centrifugation of the medium. At this point the unintroduced microbiologist who fastidiously seeks to preserve the integrity and the hidden identity of the unknown culture throughout a continuum of transfers to a large variety of new substrates, seeking such answers as: does the unknown ferment various sugars?--produce gas, acid, change the color of the medium, exhibit motility, and so on?--would be horrified to see the bacterial cells discarded as being of no further use.

The supernatant is then extracted thrice with ether which, in turn, is treated with anhydrous $Na_2 SO_4$ to remove water and an aliquot of 3 microliters injected into the gas chromatograph. The extracted volatile wastes are then converted by heat into their gaseous forms by the gas chromatograph. These pass through a 6' X 1/8" column packed with 10% Carbowax 4000 terminated with terephthalic acid on Chromosorb W HMDS 60/80 mesh, which has a varied chemical affinity for the constituent molecules of the compounds in transit. Segregation of entities is achieved by patterns of compounds slowed by varying chemical activity within the column. Nitrogen flowing at a rate of 40 ml per minute through the column serves as the carrier gas.

As each of these distinct compounds emerges from the column, it is recorded on a graph as a result of being passed through a flame ionization detector (FID) and an electron capture detector (ECD). Each compound produces a distinct peak on the printout with

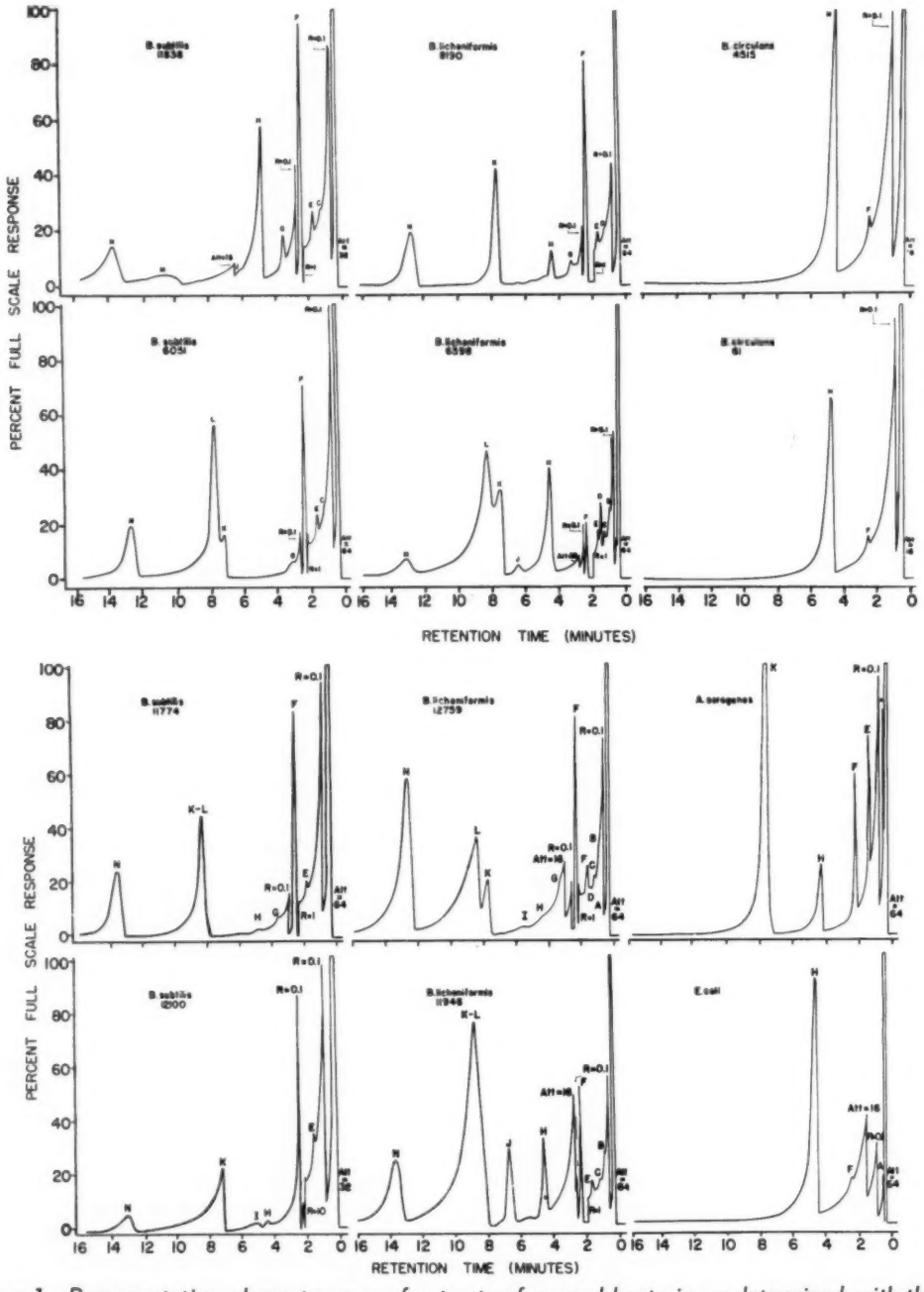

Figure 1. Representative chromatograms of extracts of several bacteria as determined with the flame ionization detector. F refers to the range on the detector and Att is the attenuation.

peak areas of 10 mm^2, or greater, serving as major peaks for consideration. The ECD was found to be the more sensitive, with samples being diluted up to 80-fold, while FID samples were concentrated 10-fold. Prime metabolites responsible for peaks are acetoin, diacetyl, ethyl alcohol, acetic, proprionic and butyric acids and 2,3 butanediol. So sensitive is the ECD to diacetyl and acetoin that characteristic peaking is obtained from an 0.0063 microliter of original medium, and product equivalent to a detection capability of 16 cells appears possible. Fig. 1 presents representative chromatograms determined with the flame ionization detector, and Fig. 2 presents several as determined with the electron capture detector.

As each compound of the total metabolic waste of a pure culture is recorded, an easily identified profile emerges. Each profile, signature, or "fingerprint" can then be compared with known signatures for purposes of identification.

Work could progress toward the creation of a library of bacterial signatures which, when sorted in automated information-retrieval systems, would provide for an almost immediate central-file printout of the identity of an unknown organism.

The utilization of methods employing chromatography, computerized linear portrayal, and automated information retrieval may revolutionize existing methods for the detection and identification of pathogens in human and veterinary medicine. Further investigation proceeding from this research base may provide for far-reaching benefits in those fields of agriculture and industry where domesticated bacteria play valuable roles in the production of numerous and valuable chemical substances from known substrates.

Certain bacteria, such as lactic and proprionic-acid bacteria important to the production of yogurt and cheese, or those necessary to bring about the synthesis of butanediol from glucose and starchy substances used in the manufacture of synthetic

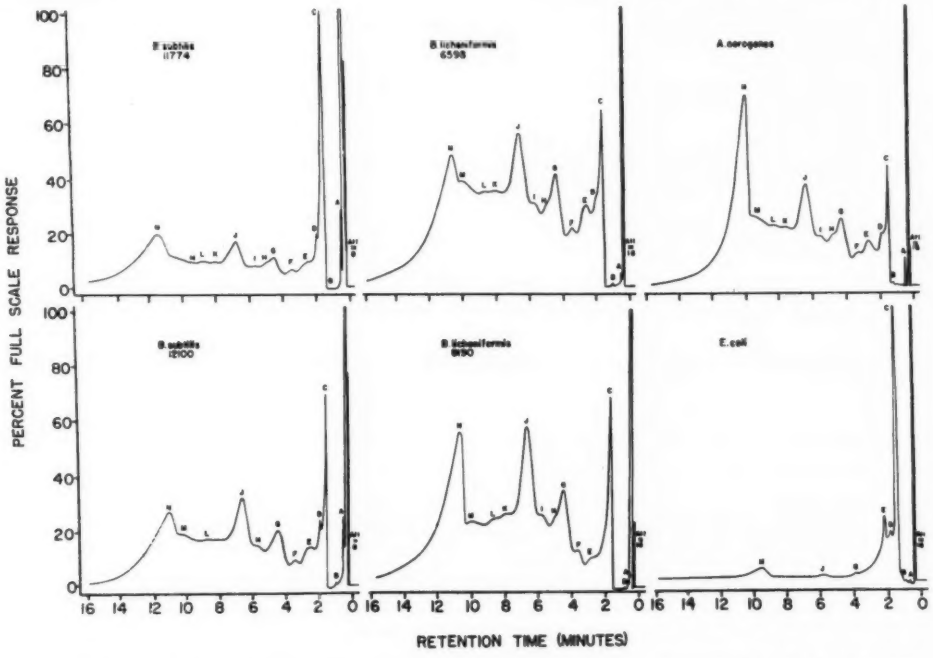

Figure 2. Representative chromatograms of several bacteria as determined with the electron capture detector. The ether extract of the medium was either undiluted (Escherichia coli) or diluted 4- (Aerobacter aerogenes), 40- (Bacillus licheniformis), or 80-fold (Bacillus subtilis) before a sample was injected into the instrument.

rubber, must be maintained in pure cultures in order to achieve desired results. Industries using them are constantly on the alert to detect any contamination or changes within these domesticated stock colonies resulting from spontaneous mutations. These mutations may affect the morphology, metabolic properties or pathogenicity of the organism.

Other investigations may provide for benefits to those industries that utilize pure cultures of molds to produce many of our life-saving antibiotics. The fields of virology, and the study of rickettsia, may also benefit from future applications of this research base. The same holds true for the brewing and fermentation industries, as well as for the baking enterprises, if yeasts would yield to such rapid identification methods.

The field of gnotobiotic (germ-free) research which utilizes an array of standardized biological models, i.e., the rat, mouse, guinea pig, monkey, dog, cat, and so on, could also benefit from the rapid detection of an organism introduced into the gnotobiotic environment.

Will resting cultures yield to these methods? With chromatographically clean media, there is every reason to believe they will. Will mixed cultures yield to these methods? This question at present remains unanswered. However, the possible utilization of new media which would bring about the generation of unique dead-end metabolites, or the application of sophisticated cross-correlational techniques to a maze of peaks may provide a path to the answer.

In the vast array of viral diseases, serum-neutralizing or complement-fixing antibodies and hemagglutination-inhibition testing are often used to identify the viral agent responsible. Many days to weeks are frequently required for body-response products to the viral antigens to appear in the circulatory system in quantity sufficient to enable such procedures.

Perhaps viral/cellular metabolites or changes can be detected in the circulating sera of host animals within a few days of infection and prior to the first noticeable clinical symptoms of a viral disease syndrome, which often herald the first signal that an individual of a population at risk has in fact been the unwilling partner in the transmission of disease. Such applications to high-risk populations, or to several individuals to be screened for latent viral agents prior to extended periods of high-intensity performance where an acute disease manifestation would be intolerable, would certainly be of merit.

Ongoing work in this exciting area results from the dedicated efforts of the principal investigator and a smooth coupling transition from AFOSR's basic-research sponsorship to exploratory research administered by the Aerospace Medical Division, Air Force Systems Command. ✪

Magnetic Events Occurring Within Two Seconds After Nuclear Detonation

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

During the first 2 seconds after a high-altitude nuclear detonation, 2 distinct signals are detected at stations all over the world. The stronger of these signals occurs between 1.5 and 2 seconds after detonation. But a weaker signal with an amplitude of only about one tenth to one hundredth the amplitude precedes the stronger signal. This first, weaker signal occurs at the worldwide net of stations within a few tenths of a second after the detonation. The first signal, the prompt signal, has an amplitude on the order of tenths of gammas and is detected at frequencies above 1 Hz. The second signal, with characteristic amplitudes greater than 1 gamma, has a frequency of less than 1 Hz.

Dr. Philip Newman of AFCRL and S. L. Kahalas of Mt. Auburn Research Associates have made a thorough analysis of these worldwide nuclear-induced magnetic disturbances, and have explored several mechanisms that might explain the generation and propagation of both the prompt and the second signal. They attribute the prompt

signal to the electromagnetic pulse which is produced at a height of about 30 km by gamma rays from the detonation. This pulse then travels at the speed of light within the earth-ionospheric cavity, taking an eighth of a second to travel around the world. But there are other possible mechanisms which can generate a prompt magnetic disturbance at large distances from the detonation.

One of these is neutron-decay beta effects. Neutrons are emitted by the bomb in all directions. These travel very quickly to far distances and decay into a proton and an electron. The electron, in turn, will spiral along the geomagnetic field line and produce a magnetic disturbance either by Cerenkov radiation or by creating enhanced ionization in the D and E regions. It is also possible for the neutron-decay protons to produce a similar effect, although it takes them longer to arrive at a given station than the electrons.

Another possible mechanism is that of whistlers. But both whistlers and neutron-decay effects would be strongly influenced by the earth's magnetic field, resulting in a selective detection at geographically favorable locations. There was no evidence in the data that this occurred. Newman and Kahalas tend to discount (but not altogether discard) neutron-decay beta effects and whistlers as possible generating mechanisms.

Neutron-decay beta effects were also considered as a possible mechanism for the second, stronger signal; but these effects were shown to be even less likely than in the case of the prompt signal.

Another conjecture concerning the origin of the second signal is that the magnetohydrodynamic wave so generated is propagated in ducts above 1,000 km in the upper ionosphere to the observing stations. But after computing the arrival times of the signals at the various stations and finding a disparity between the observed arrival times and the computed times, Newman and Kahalas determined this model to be questionable.

The most likely mechanism for the second signal, Newman and Kahalas conclude, is one in which the fireball of the nuclear detonation c r e a t e s magnetohydrodynamic waves, as before, but in which some of this wave energy propagates downward and is converted into electromagnetic waves in the lower ionosphere. These waves then propagate in the earth's ionospheric cavity at the speed of light. Calculations based on this model are in general agreement with observations.

Both the prompt signal and the second signal, then, seem to depend on the propagation of the signal in the cavity between the surface of the earth and the lower ionosphere. The prompt signal seems to be generated directly by the detonations. The second signal seems to be generated indirectly by magnetohydrodynamic excitation of the earth-ionospheric cavity.

Dr. Philip Newman, senior scientist in the Upper Atmosphere Physics Laboratory, AFCRL, received his B.S. magna cum laude from the City College of New York in 1924, his M.A. in Physics from Columbia University in 1925, and his Ph.D. in Mathematics, also from Columbia, in 1941. He is currently doing basic research in the field of electromagnetic propagation through the atmosphere which will contribute new theory and knowledge to the physics of the upper atmosphere. In 1946, Dr. Newman formulated and implemented the first Air Force program in radio propagation, some elements of which -- such as the VLF program and the proposal for an ionospheric radar for missile detection -- have continued to the present. In the period 1952-1963, he set up and headed the Propagation Sciences Laboratory at AFCRC (later AFCRL) where he directed studies in ionospheric and tropospheric scatter, meteor propagation, whistler propagation, techniques for the location of nuclear detonations, and other areas. He is a member of Phi Beta Kappa, IEEE, the American Physical Society, the American Geophysical Union, and AAAS.

AFCRL Rocket Used To Study Re-entry Communications Problems

MICROWAVE PHYSICS
LABORATORY, AFCRL

An experiment designed to study techniques for improving communications with space vehicles re-entering the earth's atmosphere was conducted on June 28, 1967, from Wallops Island, Virginia, by AFCRL scientists.

A Trailblazer II--a 4-stage, solid-propellant rocket--carried an electronically instrumented 65-pound hemisphere-cone payload to an altitude of about 187 miles. At that peak altitude, the third- and fourth-stage engines propelled the nose cone downward. On its descent, and at a height of 60 miles above the earth's surface, it achieved a velocity of 18,000 feet per second, thus creating an envelope of hot ionized gas--the plasma which blocks radio and microwave communications with a re-entering vehicle.

To keep the plasma as pure as possible so as to insure a successful experiment, no ablative coating was used on the nose cone. The unprotected re-entry vehicle was completely destroyed by the frictional heating of the atmosphere shortly after experimental measurements were completed.

Severe attenuation or complete blackout of telemetry, communications, and navigational functions are caused by the plasma sheath. While the few minutes of blackout that accompany re-entry on a ballistic trajectory did not prove unduly serious on Mercury and Gemini flights, the longer blackout of 30 minutes or so anticipated on the coming generation of glide vehicles is a principal matter of concern.

A satisfactory solution to the re-entry communications problem can be found through careful measurements of plasma-sheath properties and their effects. Results of these measurements can be used to develop techniques for predicting the exact behavior of a radiating system during re-entry. Based on these predictions, scientists will be able to select the best antenna configuration, determine its placement on a vehicle, and also choose its operating power and frequency.

The experiment included measurements of nonlinear pulse-shape distortion, interantenna coupling, antenna impedance mismatch, antenna voltage breakdown, antenna pattern distortion, and plasma-sheath attenuation at S band. Similar measurements were made at X band with the exception of nonlinear pulse-shape distortion and interantenna coupling. Electron-density-profile measurements were made with flush-mounted Langmuir probes, and also independently with electroacoustic probes. These high-power

Mr. Joseph L. Poirier is an electronic engineer with the Plasma Electromagnetic Branch, Microwave Physics Laboratory, AFCRL, investigating the propagation of electromagnetic energy through the plasma sheath that surrounds re-entry vehicles. He is also studying plasma simulation and the voltage breakdown of antennas at high altitudes. Mr. Poirier received his B.S. magna cum laude (1958), and his M.S. (1959), both in Electronic Engineering, and both from the Lowell Technological Institute, Lowell, Mass. He has done work in the environmental testing of missile subsystems for the Bell Aircraft Company. Also, as a lieutenant in the Air Force assigned to the Electromagnetic Radiation Laboratory, RADC, he has been concerned with problems of communication through plasmas.

measurements complemented a series of similar low-power microwave tests conducted by the Ohio State University, under contract to the Air Force Avionics Laboratory, during 1966.

This was the first in a series of three rocket launches scheduled by AFCRL for re-entry communication studies. The second experiment is planned for later this year, with the last in the series forecast for the early spring of 1968.

J. Leon Poirier, of the AFCRL Microwave Physics Laboratory, is the project scientist for this program.

Mr. John D. Antonucci, of AFCRL, adjusts an S-band cavity antenna that will be placed at the stagnation point (top of the nose cone) of the Trailblazer II vehicle. Nearby on the bench are other antenna configurations, including the X-band telemetry antenna. The nose cone is part of the fourth stage of the rocket.

OZONE and the Earth's Heat Budget

METEOROLOGY LABORATORY, AFCRL

The heat balance of the earth's atmosphere--the amount of heat received from the sun against that which is reradiated back into space--maintains remarkable equilibrium. Were this untrue we could expect wide and erratic swings in temperature over the earth from season to season and from year to year.

In any set of equations dealing with the atmospheric heat budget, ozone absorption in the stratosphere is a fundamental factor. For example, at about 30 km (10 mb), ozone absorption of direct solar energy contributes more than 80 percent to the earth's heat, with another 10 percent of the heating resulting from ozone absorption of reflected radiation from the earth and clouds. At about 20 km (50 mb), these figures are 70 and 15 percent, respectively.

The importance of ozone in the functioning of the earth's giant meteorological machine led AFCRL, in 1963, to establish an extensive ozone data-collecting network covering half a hemisphere. The network consists of 11 stations extending from Alaska and Greenland in the Arctic to Grand Turk Island and the Canal Zone in the equatorial regions. Once a week (every Wednesday) balloons carrying ozone-measuring instruments are released simultaneously from each of these stations. Special 2-week periods are scheduled for more intensive daily observations. Instruments were designed to collect information on stratospheric ozone up to 30 km.

Wayne S. Hering, C. N. Touart and Thomas R. Borden, Jr., of AFCRL have recently applied the resultant wealth of ozone data to problems of the stratoshperic heat balance. In the lower level of the atmosphere--the troposphere--convection from the earth's surface is the major source of atmospheric heat. But the AFCRL study is confined to the stratospheric heat balance. The result of the study is a greatly simplified model of the radiative balance in the stratosphere, a model which permits the prediction of stratospheric temperatures, at least in the warmer half of the year, with remarkable accuracy.

Three factors are involved in stratospheric temperature changes--solar heating, transport of heat by atmospheric circulations, and radiative (infrared) cooling. Data on ozone concentrations gathered by the AFCRL network provide a basis for calculating total solar heating with an accuracy not previously possible. The net effect of the two other factors--transport and radiative cooling--can be evaluated simply by subtracting the calculated solar heating rate of ozone from the observed temperature change. This net effect is called the "balance requirements."

When this is done, one would expect to find an erratic relationship between the balance requirements and the observed mean monthly temperature. This would be expected for two reasons. The first is the fluctuations in temperature in the stratosphere due to atmospheric transport processes; the second is the expectation that heat is lost to space and exchanged with other levels by infrared emission and absorption in some nonlinear relationship to temperature. The three AFCRL scientists were surprised to find that for the warmer months, May through October, this is not the case. Instead, the balance requirements are a linear function of temperature.

This discovery has several interesting implications. One is that during the warm months the stratosphere must be in radiative equilibrium on the average. In other words, transport processes contribute negligibly to the change of monthly mean temperature. This is, of course, the classical view of the stratosphere; but in recent years it has been increasingly challenged. The AFCRL scientists have now substantiated the classical hypothesis.

Another implication is that the net infrared transfer of heat in the stratosphere can be calculated by an enormously simplified yet

effective procedure. Although approximations have been previously suggested by others, the AFCRL study is the first to provide validating evidence. The dramatic proof of the new AFCRL procedure is its ability to account for the observed mean temperature at all latitudes in the lower stratosphere with a standard error of only about 2 degrees C.

Messrs Chankey N. Touart, Wayne S. Hering, and Thomas R. Borden, Jr., (l. to r.) are with the Meteorology Laboratory, AFCRL.

Mr. Touart, Senior Scientist (heat transfer), received his B.S. in Physics from the University of Chicago in 1940 and studied meteorology there in 1941 as an Army Air Corps cadet. As a laboratory chief at AFCRL from 1951 to 1961, he participated in many of the principal research movements in postwar meteorology. Since 1961 he has conducted research on a variety of topics, including radiative transport, boundary-layer phenomena, eddy transport in the stratosphere, and hydrodynamical models. Mr. Touart has also participated in numerous study groups, including the 1964 NAS-NRC Special Study of the Atmospheric Sciences. He is a member of the American Meteorological Society, the Americal Geophysical Union, RESA, AAAS, and Phi Beta Kappa, and has several publications to his credit.

Mr. Hering, Chief of the Upper Atmosphere Branch, Meteorology Laboratory, received his B.S. from the University of Illinois in 1948 and his M.S. in Meteorology from MIT in 1959. After serving as a Weather Officer in the Army Air Corps in World War II, he became a research scientist with the Army Corps of Engineers. Upon joining the Geophysical Research Directorate (a component of AFCRC, the predecessor of AFCRL) in 1951, Mr. Hering worked as a project scientist toward the development of improved weather-analysis and forecasting methods. He is now engaged in planning and conducting a variety of descriptive and theoretical investigations of the circulation of the upper atmosphere. Mr. Hering is a member of the American Meteorological Society and the American Geophysical Union.

Mr. Borden, a research meteorologist with the Upper Atmosphere Branch, Meteorology Laboratory, completed Weather Observer and Weather Equipment Teletype Technician training courses while in the Air Force from 1946 to 1949. During 1956-1957, he took courses with General Electric and IBM in programming electronic data-processing machines. He has received further programming training at L G Hanscom Field, and has completed courses in mathematics and physics given by the University of Massachusetts Extension Division. Mr. Borden is currently considering the problems of radiative transfer due to the absorption of solar radiation by ozone. He is a member of the American Meteorological Society.

Limited War Research At AFCRL

LT COL LEON STONE
Technical Plans and Operations Office, AFCRL

AFCRL scientists, responding to the need for new or special technologies for limited war application, have initiated some 20 projects directly related to military problems in Southeast Asia. About 10 per cent of the total AFCRL budget is spent on these projects--some $4 million. These Southeast Asia efforts cover meteorology, communications, detection, surveillance and reconnaissance.

Because weather is a major limiting factor in Southeast Asia operations, AFCRL has concentrated attention on techniques and equipments that will give more precise data on wind, rain and clouds. In addition to specific equipments, a more general study has focused on tropical meteorology using data collected by weather satellites. Part of this work includes a climatological study aimed at solving forecasting problems in Southeast Asia, particularly during the monsoon season.

In the area of communications, AFCRL is conducting a program in which inexpensive aerosols would be used to artificially create an ionosphere at 60,000 to 80,000 feet. Signals would then be reflected from this layer, thus extending the range of horizon-limited communications.

Detection, surveillance and reconnaissance are basic functions in any military operation, but in SEA they pose special difficulties. AFCRL scientists are investigating low-light-level television techniques for nighttime surveillance and reconnaissance.

AFCRL is also applying infrared techniques in novel equipment configurations to detection, reconnaissance, and surveillance schemes. A readout technique resulting in high-quality data has been developed and is being applied for use with infrared instrumentation for thermal enhancement of the sensed scene.

Among the meteorological sensors, equipments and techniques under development or test are:

1) An expendable, simple weather station which can be used in remote areas and which will provide data on wind speed and direction, rainfall, accumulative rainfall and temperature.

2) A low-altitude atmospheric sounding rocket capable of providing wind and temperature data up to an altitude of about 3,000 feet which will be tested this spring at Eglin Air Force Base, Florida.

3) A lightweight, rugged, high-performance, hand-held wind-measuring set that will provide wind velocities and gust data with greater accuracy and resolution.

4) An expendable gas cylinder to inflate weather balloons. Each of these lightweight

Lt Col Leon Stone is Assistant for Limited War and also Chief, Scientific Liaison Branch, Evaluations Division, Deputy for Technical Plans and Operations, AFCRL. He has a B.S. in Chemistry from Northeastern University and has completed Aircraft Observer, Advanced Chemical Warfare, Aviation Ordnance, and Weaponeer training at various service schools. He is a member of the American Chemical Society, the National Geographic Society, and the American Association for the Advancement of Science.

cylinders will be capable of inflating several such balloons.

5) A covert ceilometer designed to measure the cloud-ceiling altitude in areas of enemy activity.

6) Also, for purposes of covert weather operations, AFCRL has developed and successfully tested a device which permits termination of weather balloon flights before the balloons reach an altitude where the possibility of chance observation by the enemy increases. This piece of equipment quietly terminates the balloon flight at a predetermined altitude by slashing a hole in the side of the balloon. The puncturing device is an aid to weather officers in forward areas as they collect information needed in preparation for low-altitude aircraft operations. ✪

Flow Visualization In An Incompressible Medium

IST LT ERIC G. FRIBERG, Fluid Dynamics Facilities Research Laboratory, ARL

Very often much useful information can be obtained from a qualitative picture of the flow about test bodies in subsonic or supersonic streams. The familiar schlieren and shadowgraph methods for viewing compressible gas flows indicate density variations in the flow field, thus permitting the visualization of shocks, separation regions, wakes, etc. On the other end of the spectrum, incompressible flow is often visualized by adding smoke, dyes, or solid particles to the flow medium. This note describes the hydrogen-bubble method of flow visualization and various qualitative results obtained with it.

The basic assumption, inherent in any visualization by the addition of a foreign medium to the flow, is that this medium moves with the flow and with the same velocity and direction. By photographing this additive, one can infer the motion of the flow. Classic results, well known to all fluid dynamicists, are the flow-visualization photographs of Ludwig Prandtl.(1) Yet the major difficulty with aluminum particles, beads, dyes, or smokes (as used in low-speed wind tunnels) is the problem of obtaining a uniform distribution in the flow medium. Unique among these approaches is flow visualization in water by the method of hydrogen bubbles, which can be accomplished quite simply and with a minimum of equipment.

In a water table, hydrogen bubbles may be produced by the simple electrolysis of water. There are two major attractions to the method: (1) hydrogen bubbles permit excellent

1st Lt Eric G. Friberg is assigned to the Fluid Dynamics Facilities Research Laboratory, ARL. As a project engineer on the Mach-14 hypersonic wind tunnel, his primary responsibilities are to assure the operation of, and assist testing in, this vital facility. He has under his direction several projects related to facilities research.

In 1964, Lt Friberg was graduated from Harvard University with an A.B. in Engineering and Applied Physics, after which he entered graduate school at M.I.T. where he obtained his S.M. in Aeronautics and Astronautics in 1965. He is currently enrolled at the Ohio State University as a doctoral candidate in Aeronautics and Astronautics.

Lt Friberg received his commission through the AFROTC program in June 1964 and took an educational delay to obtain his master's degree. Since September 1965, he has been assigned to the Aerospace Research Laboratories.

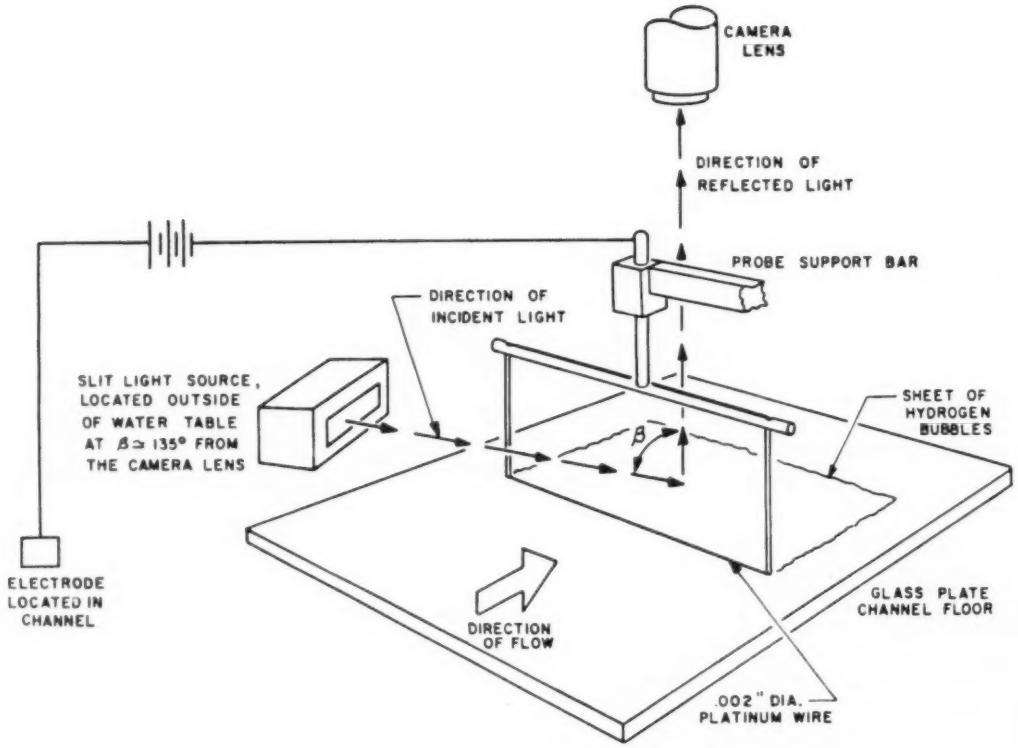
CAMERA LENS
DIRECTION OF REFLECTED LIGHT
PROBE SUPPORT BAR
DIRECTION OF INCIDENT LIGHT
SLIT LIGHT SOURCE, LOCATED OUTSIDE OF WATER TABLE AT β≃ 135° FROM THE CAMERA LENS
SHEET OF HYDROGEN BUBBLES
β
ELECTRODE LOCATED IN CHANNEL
DIRECTION OF FLOW
GLASS PLATE CHANNEL FLOOR
.002" DIA. PLATINUM WIRE

Figure 1. Schematic of hydrogen-bubble technique for flow visualization.

flow visualization, do not contaminate the water, and are inexpensive to use; and (2) the bubble size is sufficiently small so that the reaction to changes in the flow field is almost instantaneous. The technique was first used by Geller (2) and later studied qualitatively by Schraub, et al.(3) This method has proved most applicable in water in the speed range 1 in/sec to 1 ft/sec, although recent work at the David Taylor Model Basin by G. E. Mattingly indicates the method may even be applied at velocities up to 20 ft/sec.

Hydrogen bubbles are formed by making the generating wire the negative electrode of a d.c. circuit. The bubbles are then formed on the wire and are wiped into the flow by the medium passing over the wire. Bubble diameter is approximately that of the wire and, in order to keep the rise time of the bubbles large, wires of 0.004 inches in diameter or less should be used. Small wire diameters are further dictated by the necessity to keep the Reynolds number of the wire less than 50, so that no disturbances will be generated by the wire itself. The bubbles may be dispensed in a plane sheet as shown schematically in Figure 1, or as a line source by kinking the wire. These line sources then

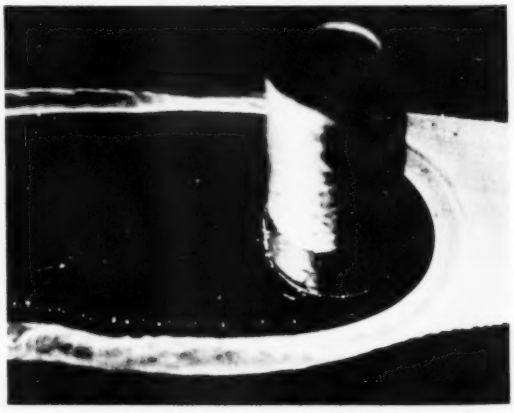

Figure 2. Visualization of a horseshoe vortex. Flow is from right to left.

follow the streaklines of the flow. The voltages and currents needed vary with the flow velocity. In these studies, best results were obtained with platinum wires 0.002 inches in diameter with an operating voltage of 100 volts at 50 milliamps.

An example of the planar-flow results around a two-dimensional model is shown in Figure 2 in the visualization of a horseshoe vortex at the base of a circular cylinder. Figure 3 shows the streaklines around a two-dimensional elliptic model. Motion pictures of flow patterns such as these were used to determine the time-varying angular position of the separation point of the vortex feeding sheet about two-dimensional circular and elliptic models. A more thorough discussion of these experiments, and the results, are given in Reference 4.

Figure 3. Streaklines around an elliptic cylinder.

Although extensive work has been done for two-dimensional methods of flow visualization, little work has been done to apply the technique directly to three-dimensional or axisymmetric models. This method was successfully applied to the above cases in a water tank at the MIT Aerophysics Laboratory by making the model the negative electrode in the electrolysis process.(5) As the body enters the water, hydrogen bubbles form at the tip of the model, the tip being initially the region of highest potential. After submerging, and as the potential is uniformly distributed over the body, the bubbles then begin to form along the entire surface of the model. The bubbles are again swept off the surface by the passing medium and wrap up into a spiraling bubble train concentrated about each vortex core. Additional bubbles, which are not swept off the surface, are seen to congregate along the vortex separation line. An example of this visualization showing the flow about a 5^{o} circular cone with a bursting vortex is given in Figure 4. The bubble concentration about the vortex core is evident; however, the separation line is not well reproduced in this photograph.

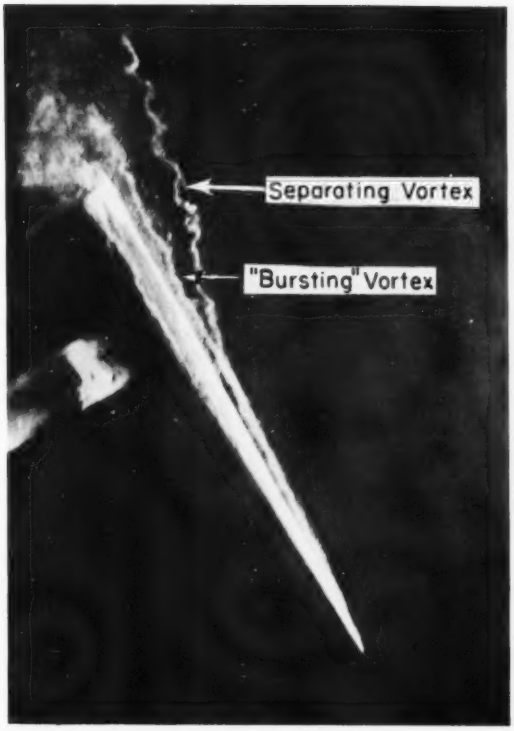

Figure 4. Flow about a circular cone at angle of attack.

In conclusion, the technique of employing hydrogen bubbles for flow visualization has

been shown to be both extremely simple and easy to apply. Excellent results may be obtained for both two-dimensional and three-dimensional problems of flow visualization in water.

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to mechanize: is that the question?

ROWENA SWANSON,

Directorate of Information Sciences, AFOSR

The computer is upon us! When one has a large item-listing and sorting job to do, the obvious way to get it done is to "get a computer to do it," as the saying goes.

This is what Professor Y. S. Touloukian of Purdue University and director of its Thermophysical Properties Research Center (TPRC) decided to do. The TPRC is a Department of Defense information analysis center, partially sponsored by the Air Force Materials Laboratory at Wright-Patterson Air Force Base. It is a national center for information retrieval and analysis of the thermophysical properties of materials. It compiles data tables; it generates critical tables of standard reference data as a component of the National Bureau of Standard's National Standard Reference Data Program; it conducts in-house experimental research on thermophysical properties; it performs reference services in response to inquiries; and its senior staff directs Master's and Doctoral dissertations of graduate students at Purdue.

In 1956, Professor Touloukian began an effort to obtain titles of Master's theses in the pure and applied sciences from all accredited colleges and universities having graduate programs in these areas. These academic dissertations had been found to be an important source of research information to TPRC. As a service to the colleges and universities, he published a volume, Master's Theses in the Pure and Applied Sciences, that listed the thesis titles and authors' names by institution within subject categories. Although some institutions no longer require a written thesis for a Master's degree, the number of universities with graduate programs is rapidly increasing. The growth in these programs is reflected in the number of titles reported in the Master's Theses volumes TPRC has published thus far (Figure 1). It should be noted that the publication does not list theses in mathematics or the life sciences.

The cost of publishing Volume I in 1956-57 was about $800. Volume V, with a 100% increase in contributing institutions and a fivefold increase in titles reported, cost about $10,000 and was becoming an enterprise that TPRC could not afford to maintain, both because of the dollar expense and the drain on staff time. It was at this point that Prof. Touloukian concluded: "Get a computer to do it."

In January 1964, TPRC proposed to the AFOSR Directorate of Information Sciences an inexpensive, apparently short-time research effort on automation of the Master's Theses compilation effort. A significant benefit from having these data in machine sortable form would be the capability, from a single input, of obtaining many desired end products (institution, author, and subject lists, for example). Additionally, inputs for the various years could be merged and subject searches could be conducted that would indicate patterns of research concentration over a period of time and possibly gaps of research interest.

VOLUME AND PUBLICATION DATE	THESIS YEAR	CONTRIBUTING INSTITUTIONS	TITLES REPORTED
I OCT. 1957	1955	93	1002
I	1956	93	1027
II AUG. 1958	1957	154	1727
III OCT. 1959(2)	1958	139	3736
IV DEC. 1960	1959	162	4984
V DEC. 1961	1960	183	5708
VI AUG. 1966	1961	186	5911
VII AUG. 1966	1962	186	6321
VIII AUG. 1966	1963	175	6505

(2) PART TWO, OF VOLUME II, INCLUDES DOCTORAL DISSERTATIONS FROM THE 1956-57 SCHOOL YEAR, CITING 2846 TITLES FROM 103 UNIVERSITIES.

Figure 1. Master's Theses volumes published by TPRC reflect growing graduate programs in accredited colleges and universities.

Figure 1 shows a period of more than 4 1/2 years between the publication of Volumes V and VI, and the publication of VI, VII, and VIII simultaneously. The story is simply told. "Canned" programs for subject sorts were not readily obtainable in 1964. "Expert" advice resulted in encoded formats that didn't match with computer programs written for them,

SUBJECT CATEGORIES, MASTER'S THESES

AEROSPACE ENGINEERING
AGRICULTURAL ENGINEERING
ARCHITECTURAL ENGINEERING
ASTRONOMY
ASTROPHYSICS
CERAMIC ENGINEERING
CHEMICAL ENGINEERING
CHEMISTRY
CIVIL ENGINEERING
COMMUNICATIONS ENGINEERING
ELECTRICAL ENGINEERING
ENGINEERING MECHANICS
ENGINEERING PHYSICS
ENGINEERING SCIENCE
FUELS AND COMBUSTION
GENERAL ENGINEERING
GEOCHEMISTRY
GEOLOGICAL & GEOPHYSICAL ENGINEERING
GEOLOGY
GEOPHYSICS
INDUSTRIAL ENGINEERING
IRRIGATION ENGINEERING
MARINE ENGINEERING
MATERIALS ENGINEERING
MECHANICAL ENGINEERING
METALLURGY
METEOROLOGY
MINERALOGY & PETROLOGY
MINING & METALLURGICAL ENG.
NUCLEAR ENGINEERING
NUCLEAR PHYSICS
OCEANOGRAPHY
PETROLEUM & NATURAL GAS ENG.
PHOTOGRAMMETRIC & GEODETIC ENG.
PHYSICS
PLASTICS ENGINEERING
PULP & PAPER TECHNOLOGY
REACTOR SCIENCE
SANITARY ENGINEERING
TEXTILE TECHNOLOGY
TRANSPORTATION ENGINEERING

Figure 2. The 41 subject specialties under which thesis entries are grouped in Volumes VI, VII, and VIII of Master's Theses.

and programs that couldn't be debugged. After approaching the problem the "easy" way, the decision to write essentially new programs was made. These became operational in December, 1965. The final report for this effort notes that the IBM KWIC system (IBM 1401/1460 Program Library 1401-CR-02X) was the basis for program development; but the report states further that "just one program in this system escaped rewriting."(1)

Volumes VI, VII, and VIII of Master's Theses do not, as their predecessors did, have a subject index to the thesis entries. They are, however, grouped within 41 subject specialties (Figure 2), alphabetically by institution within subject, and alphabetically by author within institution (Figure 3). The plus factor from this effort, in addition to experience, is the existence of a set of programs that generates subject indexes (Figure 4) of greater specificity than time permitted to be done manually. Moreover, the mechanization reduced production costs from about $10,000 to approximately $2,000 per volume, more than half of which represents printing costs. Volume IX is in press. A 1967 publication date is achievable for Volumes X and XI as well. Professor Touloukian was originally unable to publish Volume VI because of a lack of funds. The time and cost reductions realized by mechanization now make continued publication economically possible as a self-sustaining operation.*

**Master's Theses* is available at a modest cost from TPRC. Limited quantities of Volumes I and II are available at $3.00 each. Volumes III to VIII are available at $6.00 each. Sets of eight volumes may be purchased for $34.00.*

PHYSICS (CONTINUED)

HAWAII, UNIVERSITY OF

TOTAL ABSORPTION AND PHOTOIONIZATION CROSS SECTIONS OF XENON IN THE SPECTRAL REGION 855-1025 A / JACKSON R S 63-063-38

HOUSTON, UNIVERSITY OF

THE MEASUREMENT OF SPUTTERING YIELD OF POLYCRYSTALLINE COPPER USING A CALIBRATED QUARTZ CRYSTAL AS A FACTOR / CORKE P E 63-065-38

HYDRODYNAMIC FACTORS AFFECTING THE SITES OF PARTICULATE DEPOSITION IN TUBULAR SYSTEMS / KILPPER R W 63-065-38

A METHOD FOR REPRODUCING MOVEMENTS OF THE MANDIBLE / MORRISON W E 63-065-38

SPUTTERING OF MONOCRYSTALLINE COPPER BY 40-190 KEV ARGON IONS / PATTERSON R L 63-065-38

HOWARD UNIVERSITY

ENERGY DISTRIBUTION OF ALPHA PARTICLES AS A FUNCTION OF THE THICKNESS OF THE SOURCE / ALCORN G E JR 63-066-38

THE OPERATION OF THE 60 DEGREE MASS SPECTROMETER AND ELECTRON IMPACT STUDIES IN MONOMETHYLAMINE / DARBY A J 63-066-38

SOLID STATE MASS SPECTROMETRY STUDIES / DOUGLAS N J JR 63-066-38

SCATTERING OF MODIFIED COULOMB POTENTIALS / LAWSON J D 63-066-38

THEORY OF SCATTERING OF PLANE WAVES BY A SOFT SPHERE / SHEPPARD R J 63-066-38

THE FRESNEL EDGE DIFFRACTION OF ELECTRONS / STEELE J D 63-066-38

IDAHO, UNIVERSITY OF

THE RING CURRENT AND NORTH-SOUTH MOTION OF AURORA / HAGEN J B 63-067-38

FILTRATION OF AIR OF RADIOACTIVE EFFLUENT / SAWYERS J E 63-067-38

ILLINOIS INSTITUTE OF TECHNOLOGY

MAGNETRON OPERATION BY TRANSIT TIME ANALYSIS / DUNN L R 63-069-38

THERMAL EXPANSION MEASUREMENTS ON SAPPHIRE AND RUBIDIUM IODIDE BELOW 20 DEG K / SPARKS P W 63-072-38

JOHNS HOPKINS UNIVERSITY

CONSTRUCTION AND CALIBRATION OF AN ANTI-COMPTON SPECTROMETER / MUSCARI JR J A 63-074-38

KANSAS, UNIVERSITY OF

DIELECTRIC AND ELECTROCALORIC MEASUREMENTS IN ANTIFERROELECTRIC CRYSTALS OF AMMONIUM PERIODATE / KUPALER J R 63-075-38

RESONANCES IN THE YIELD CURVE OF THE SILICON-30(P,NU1P-31 REACTION (E SUB P EQUALS 1.5 TO 3.0 MEV RANGE) / ROBERDS R M 63-079-38

KANSAS STATE UNIVERSITY

THE PREPARATION OF THIN FILMS OF INDIUM ANTIMONIDE ON CRYSTALLINE SUBSTRATES / BEHLE A F 63-077-38

TRACK WIDTHS OF HEAVY IONS AND UNIT MAGNETIC POLES IN ELECTRON SENSITIVE NUCLEAR EMULSION / BUTTS J J JR 63-077-38

FREQUENCY SPECTRUM OF ELASTIC WAVES IN BODY CENTERED CUBIC LATTICES / CLARK B C 63-077-38

MICROWAVE MEASUREMENTS OF THE ELECTRIC DIPOLE MOMENT AND OTHER DIELECTRIC PROPERTIES OF NITROBENZENE / RHINE P E 63-077-38

KENTUCKY, UNIVERSITY OF

PION-DEUTERON CROSS SECTIONS AT 330 MEV / FAUGHN G S 63-079-38

A TEST OF THE FEASIBILITY OF STUDYING THE LOW ENERGY LEVELS OF LOW ATOMIC NUMBER, LOW DENSITY NUCLEI / KEUPER J J 63-079-38

THE CHARGED PARTICLE ANALYZER OF THE 2.5 MEV ELECTROSTATIC ACCELERATOR / MCGUIRE R F 63-079-38

OPTICAL ABSORPTION OF CALCIUM OXIDE SINGLE CRYSTALS / POWELL J A 63-079-38

ELASTIC SCATTERING IN PI EQUALS P COLLISIONS AT 604 MEV / RILEY B R 63-079-38

DISCREPANCIES AND ANOMALIES IN THE IDENTIFICATION OF HIGH ENERGY PARTICLE INTERACTIONS / STAUTBERG J L 63-079-38

Figure 3.
Master's Theses, Vol. VIII, 1963, p. 121, showing grouping by subject specialty, alphabetically by institution within subject, and alphabetically by author within institution.

The final report of the AFOSR contract with TPRC provides operating specifications for the programs by which the Master's Theses format and key-word indexes can be generated. The program documentation has been filed at the Computer Software Management and Information Center (COSMIC), a NASA-sponsored computer-program repository at the University of Georgia.**

To mechanize, is that the question? The answer seems to be negative for data bases and information-storage-and-retrieval requirements such as those of Master's Theses. Some of the more relevant questions appear to be: What programs are available? Have they been checked out? Is consultation sufficient, or is an in-house programming capability advisable? How much time will a changeover to mechanization require? What are the time and cost tradeoffs? The TPRC experience is part of the saga of how non-computer-oriented scientists are beginning to introduce the computer as an information-processing tool into their operations. They are finding, however, that getting the computer to do it really means getting a group of people together who have both an understanding of the computer and of the problem to be solved, and getting them to get the computer to do the job required.

*** COSMIC is operated by the University of Georgia Computer Center. At the present time, it is the repository primarily for unclassified NASA and AEC programs. It checks the documentation of the programs, runs them, and prepares and distributes informative abstracts about them. Card decks or tape copies of programs are available from COSMIC at nominal cost.*

REFERENCE

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DISCRETE
ERROR ANALYSIS AND CORRECTION OF DISCRETE SPACE-DISCRETE TIME ANALOG SIMULATION / DICKERSON D H 61-022-17

VIBRATION ANALYSIS OF A DISCRETE NETWORK / WOOL W L 61-041-26

A COMPARISON OF THE RESPONSE LOADINGS OF A FLEXIBLE MISSILE DUE TO DISCRETE AND RANDOM GUSTS / ROCKENFIELD D F 61-190-01

DISCRETE-FREQUENCY
BROADBAND IMPEDANCE MATCHING BY APPLYING A TCHEBYCHEFF APPROXIMATION TO DISCRETE-FREQUENCY DATA / BARES W A 61-116-12

DISCRETE-STATE
A MINIMAL COST PROBLEM IN DISCRETE-STATE SYSTEMS / SCHOTTLER P H 61-022-12

DISCRIMINATION
THE USE OF PULSE SHAPE DISCRIMINATION IN THE DETECTION OF NEUTRONS / SHELBY R N 61-168-38

DISCRIMINATOR
DESIGN OF A NARROW-BAND FREQUENCY MODULATION DISCRIMINATOR / CORYELL D A 61-128-10

AN ANALYSIS AND EVALUATION OF 4 SELECTED PULSE HEIGHT DISCRIMINATOR CIRCUITS WHICH USE TRANSISTORS AND SEMICONDUCTOR DIODES / CALVERT J D 61-164-12

Figure 4. Subject-index printout.

'Scratch-Pad' Computer Memory

DATA SCIENCES LABORATORY, AFCRL

A tiny, integrated electronic circuit that could become the basis for a new type of high-speed-computer "scratch-pad" memory has been developed by RCA under AFCRL contract. The circuits use a novel "silicon-on-sapphire" technology. They are of the standard "flip-flop" variety and can be interconnected in large arrays to form a type of high-speed-computer memory that stores information as a pattern of static electric voltages locked into the circuits rather than as magnetic energy trapped in arrays of ferrite cores.

An experimental memory employing these circuits and capable of storing 9 bits of computer information has already been built. Similar memories capable of storing up to 4,096 bits and of processing them at a rate of 20 million bits per second are feasible.

Scratch-pad or auxiliary memory is a fairly recent development brought on by the growing discrepancy in speed between the main computer memory and the "logic" or arithmetic circuits which actually process the information in a computer.

Because the main memory is now so slow relative to the logic circuitry, it has become necessary--from the points of view of economy and efficiency--to introduce a small, extremely fast secondary memory that acts as a buffer between the two by providing a place for the temporary storage of information that is in process. In fact, it is often desirable to have many such memories associated with the computer.

Such memories are not easy to build, and several approaches are presently being tried with varying degrees of success including the use of magnetic thin films, laminated ferrites, and integrated arrays of standard or field-effect transistors.

The silicon-on-sapphire technique represents a relatively new approach to this problem. Its promise lies in the fact that it makes possible the production of large arrays of silicon field-effect transistors which are electrically isolated from each other on an insulating, sapphire base. This results in circuits that are inherently faster and consume considerably less power than those produced so far through any other approach.

Solar Ultraviolet Experiment Aboard OSO-III

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

Carried aboard NASA's Orbiting Solar Observatory (OSO-III) launched March 8, 1967 from Cape Kennedy was AFCRL instrumentation for measuring solar ultraviolet radiation in the range of 200 to 1,300 angstroms. The experiment, designed by Dr. H. E. Hinteregger and Dr. L. A. Hall of AFCRL, was their third such experiment aboard satellites in the OSO series.

Extreme ultraviolet radiation is being measured by means of a specially developed monochromator. Solar radiation enters this instrument through a slit and is broken into its various radiation components by a diffraction grating. AFCRL investigations of solar ultraviolet extend back to 1952 and, in the past, have been conducted largely through rocket experiments. These rocket experiments have permitted AFCRL investigators to measure the penetration of solar ultraviolet through various layers of the atmosphere.

The AFCRL OSO-III equipment will permit the clear observation of solar ultraviolet unattenuated by the earth's atmosphere. It represents 9 experiments designed to study the sun and its influence on the earth's atmosphere. The satellite is in a near-circular orbit with an apogee of 354 miles and a perigee of 336 miles. It has an inclination of 33 degrees.